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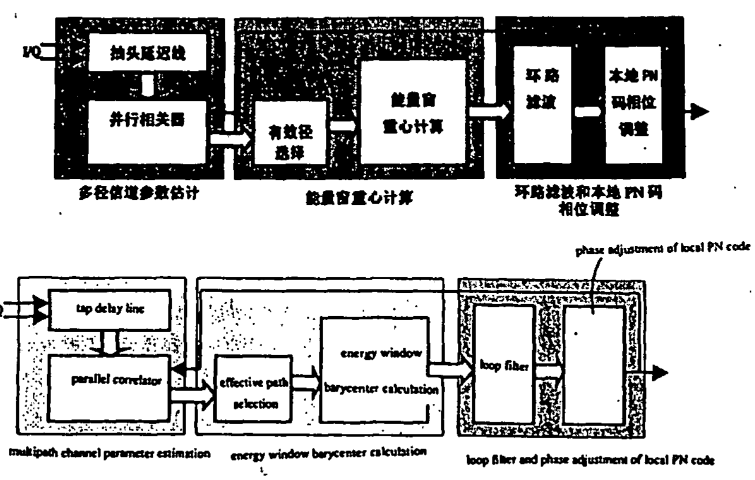
(54) Title: PILOT CHANNEL TRACKING METHOD BASED ON MULTIPATH BARYCENTER TRACKING LOOP

(54) 发明名称: 基于多径信道重心跟踪环路的导频信道跟踪方法



(57) Abstract: A pilot channel tracking method based on multipath barycenter tracking loop, comprising: 1) estimating parameter of multipath fading channel; 2) calculating multipath energy window center; 3) adjusting loop-filter and spread sequence code phase. The present invention does not need to individually track each delay path, thereby advancing a tracking performance of spread receiver and a stability of timing restoring. For a tracking of pilot signal transmitted by multi-transmitting signal source, only a multipath channnel estimator and a multipath energy window barycenter calculator are made in TDM, thereby saving hardware resource. Therefore, an integral new type coherent spread receiver can be constituted by cooperating with other part each other.

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(57) 摘要

一种基于多径信道重心跟踪环路的导频信道跟踪方法，包括步骤：

（1） 估计多径衰落信道参数；

（2） 计算多径能量窗中心；

（3） 环路滤波及括频序列码相位调整。

本发明无须对每一延迟路径单独跟踪，提高了扩频接收机的跟踪性能以及定时恢复的稳定性。对于多个发送信号源所发送的导频信号的跟踪，只需时分复用一个多径信道估计器和一个多径能量窗重心计算电路，节省了接收机的硬件资源。因此，其它部分相互配合起来可构成完整的新型相干扩频接收机。

基于多径信道重心跟踪环路的导频信道跟踪方法

技术领域

本发明涉及 CDMA（码分多址）蜂窝通信系统，特别涉及基于多径信道重心跟踪环路的导频信号跟踪方法。

背景技术

CDMA 蜂窝通信技术以其频率规划简单、系统容量大、抗多径能力强、通信质量好、电磁干扰小等特点显示出巨大的发展潜力，是未来移动通信的主流技术。CDMA 扩频信号接收机分为相干接收机和非相干接收机两种方式。相干接收机需要得知接收信号的相位信息，而非相干接收机不需要接收信号的相位信息，但要求发送信号为正交调制方式。本发明主要考虑在未来 CDMA 蜂窝系统中占主导地位的相干接收方式。

移动通信系统中存在着多径衰落现象，会造成严重的多径干扰。在采用了扩展频谱技术的 CDMA 蜂窝移动通信系统中，通过接收带有确知信息的导频（*Pilot*）信号，可以对多径信号的幅度和相位信息进行估计，从而使得多径分集和相干接收成为可能。针对多径衰落信号进行分集处理的相干扩频接收机称为 RAKE 相干接收机，它可对多个携有相同信息且衰落特性相互独立的单径信号进行相位校正并进行最大比合并处理，从而达到克服多径衰落，提高接收信号干扰比之目的。

为了实现 RAKE 接收功能，必须实现本地扩频序列（PN 码）与接收信号的同步，这种同步分别由捕获和跟踪两个步骤完成。其中捕获步骤通过对导频信道的捕获与确认完成 PN 码的初始同步（粗同步）；而跟踪步骤通过对导频信道的跟踪完成 PN 码的精细同步。两个步骤相互结合，为 RAKE 接收机提供所需的 PN 码，并为接收机提供精确的本地定时。

传统的 PN 码跟踪方法基于所谓的“迟早门（early-late-gate）”技术，通过对当前导频信号超前时刻和迟后时刻平均能量的观察和比较，对本地 PN 码的相位进行微调，从而达到 PN 码的精细同步之目的。在存在多径到达信号的条件下，可通过对每一径有效到达信号分别进行“迟早门”处理，从而实现对多径信号的精细同步。但不幸的是，由于移动通信系统中存在着严重的衰落现象，每一径到达信号在幅度和相位上均存在较大范围的随机变化，若使用传统的“迟早门”技术，则会使每一

径信号的跟踪过程随着信号的衰落变得极不稳定。此外，由于接收机本地定时的建立通常是以最早有效到达径信号为基础的，而最早有效到达径信号是极不稳定的，这使得接收机本地定时的建立缺乏稳健性。

发明内容

本发明的目的是提供一种基于多径信道重心跟踪环路的导频信号跟踪方法，其针对移动通信环境下多径信号的不确定性，引入多径能量窗概念及能量窗重心计算方法，由此建立基于多径能量窗重心的导频信号跟踪方法，从而克服传统“迟早门”处理方法所可能产生的多径信号跟踪性能恶化及本地定时信号恢复的不确定性。

为实现上述目的，基于多径信道重心跟踪环路的导频信道跟踪方法包括步骤：

（1） 估计多径衰落信道参数；

（2） 计算多径能量窗中心；

（3） 环路滤波及括频序列码相位调整。

本发明无须对每一延迟路径单独跟踪，提高了扩频接收机的跟踪性能以及定时恢复的稳定性。对于多个发送信号源所发送的导频信号的跟踪，只需时分复用一个多径信道估计器和一个多径能量窗重心计算电路，节省了接收机的硬件资源。因此，其它部分相互配合起来可构成完整的新型相干扩频接收机。

附图说明

图 1 为本发明方法步骤示意图

图 2 为本发 PN 码相位调整实现框图

图 3 为适合于多个发送信号源的多径能量窗重心跟踪环路实现框图

发明的具体实施方式

本发明提出了基于多径衰落信号能量窗重心跟踪环路的 PN 码跟踪方法，其基本思路基于以下事实：尽管在多径衰落环境下每一径到达信号的幅度和相位是随机变化的，但多径信号的能量窗口及其重心位置是相对稳定的。若根据多径信号能量窗口重心的变化调整本地的 PN 码，确定相干接收机的本地定时，并在能量窗口的范围内对有效多径进行选择，则由此所获得 PN 码跟踪方法能够有效地克服上述对单径信号进行“迟早门”处理所带来的系统定时和 PN 码跟踪特性的不确定性，从而提高相

干扩频接收机的稳健性。本发明还引入了多径能量窗的并行处理方法，使导频信号跟踪、本地定时恢复、RAKE 分集相干合并、AFC 及多小区搜索等功能的综合实现成为可能。

本发明由以下步骤构成：

1、多径衰落信道参数估计：

CDMA 系统中的导频（*Pilot*）信道用于传送事先确知的导频序列，可用于系统定时和载波的提取、信道估计、越区切换等。若系统同时发射若干个信道的信号，则等效基带接收信号可表示为：

$$r(t)=\sum_n c_n\cdot\sum_i d_i s_i(t-n/W)+z(t) \qquad \text{[公式 1]}$$

其中，d_i和$s_i(t)$表示下行信道第 i 个码分信道所发送的符号与等效基带信号；$i=0$的分项对应于 *Pilot* 信道，不失一般性，可假设导频信道所发送的符号$d_0=0$；$1/W=T_c$为一个码片的时间宽度；$z(t)$是零均值的复数白色高斯噪声；c_n为信道第 n 径的衰落因子。信道参数估计的目的在于根据接收信号$r(t)$和确知的导频序列$s_0(t)$估计出信道衰落因子c_n。

假设移动信道为频率选择性慢衰落信道模型，则可认为在一个信道估计区间内c_n近似为常数。由此可得出c_n的估计值如下：

$$\bar{c}_n=\frac{1}{NE_c}\int_0^{NT_c} r(t+nT_c)\cdot s_0^*(t)dt=c_n+N_a+N_c+N_z \qquad \text{[公式 2]}$$

式中 N_a、N_c和 N_z分别是扩频码的相关特性不够理想造成的多径干扰、多址干扰以及白噪声通过相关器后产生的输出；T_c为一个码片的时间宽度，NT_c为信道估计的积分区间；E_c是导频信道在一个码片之内的发送能量。

2、多径能量窗及其重心计算：

公式 1 中信道衰落因子c_n的有效分布范围定义为多径信号能量分布窗口（简称为多径能量窗），该窗口的大小由多径信道的时延扩展范围确定。为方便以下的讨论，设c_n的有效分布范围为$n\in[-L_1,L_2]$。在城市、乡村和山区多径衰落环境下，该窗口的大小分别约为 $3\mu S$、$6\mu S$ 和 $15\mu S$。窗口的大小与蜂窝通信系统所处的环境有关，而与所使用的频段无关。为使扩频接收机能够适用于各种环境，多径能量窗口的大小应按最大可能值选取，通常不大于 $30\mu S$，则$L=L_2-L_1+1$的取值应不大于$30\mu S/T_c$。

在多径能量窗口内，并不是所有的信号到达径均是有效的。为此应设定合适的门

限，对窗口内每一径信号的能量（也即c_n的强度）进行判决。若大于门限，则为有效到达信号径；否则则为纯干扰径（IOP）。为避免性能恶化，所有的纯干扰径均不应参加运算。判决门限的选取应略大于导频信号（PN 码）部分互相关（*Partial Correlation*）值的旁瓣值。

若用 k 表示第 k 次信道估计结果，则相应的多径能量窗的重心由 $cg(k)=cg_w(k)/cg_s(k)$ 给出，其中 $cg_w(k)$ 和 $cg_s(k)$ 的计算方法如下：

$$cg_w(k)=\sum_n n\,|\overline{c_n}(k)|^2,\qquad cg_s(k)=\sum_n |\overline{c_n}(k)|^2 \qquad \text{[公式 3]}$$

式中，n 对应于多径信道衰落因子$\overline{c_n}(k)$在多径能量窗口内所在的位置。注意公式 3 中每一参加运算的$\overline{c_n}(k)$应为大于指定门限的有效到达信号径。

3、环路滤波与本地 PN 码相位调整：

设计多径能量窗重心 PN 码跟踪环路的基本思路是，设定多径能量窗重心的目标位置为 cg_{target}，通过观察实际测量所得到的多径能量窗重心值 $cg(k)$ 与 cg_{target} 的差别，调节接收机本地 PN 码的相位，使得两者的差别尽可能小。为方便计算，设 cg_{target} 取值为零，则本地 PN 码的相位调整可简单地通过判断 $cg_w(k)$ 的极性而得到，而无需计算 $cg_s(k)$ 和 $cg(k)$。

为避免多径衰落信号的随机变化及信道估计误差所带来的误调整，应对公式 3 所得到的重心估计值进行平滑滤波。设平滑滤波后的重心估计值为$\overline{cg_w(k)}$，则 PN 相位调节方法可概括为：

若$\overline{cg_w(k)}>0$，则使本地 PN 码的相位超前δ；
若$\overline{cg_w(k)}<0$，则使本地 PN 码的相位迟后δ； [公式 4]
若$\overline{cg_w(k)}=0$，则使本地 PN 码的相位保持不变。

以下结合附图说明实施例：

由上述可知，基于多径能量窗的导频跟踪方法可分为多径信道估计、能量窗重心计算及环路滤波和 PN 码相位调整等三个部分组成。图 1 示出了多径能量窗导频跟踪的具体实施框图。各部分的具体构成及功能描述如下。

多径信道估计：该部分由抽头延迟线和并行相关器两个部分组成。抽头延迟线接收基带采样信号，采样间隔为T_c/M，M 根据具体应用可取值为 2、4 或 8。并行相关

器受外部定时的控制，完成多径能量窗口内所有多径信道衰落参数$\overline{c_n}(k)$的计算，其结果送往能量窗重心计算部分进行后续处理。

能量窗重心计算：该部分由有效径选择和能量窗重心计算两个基本单元组成。有效径选择部分单元接收前级多径信道估计输出结果，对$\overline{c_n}(k)$进行门限判决，以决定是否为有效到达径信号。判决门限的选取应略大于导频信号（PN 码）部分互相关（*Partial Correlation*）值的旁瓣值。若$\overline{c_n}(k)$的幅度值小于设定的门限，则把相应的$\overline{c_n}(k)$置为零值，并由能量窗重心计算单元完成公式 3 中所示的$cg_w(k)$的计算。其结果送往环路滤波单元。

环路滤波与本地 PN 码相位调整：环路滤波单元对$cg_w(k)$进行低通滤波运算，以获得 PN 码相位调整所需的$\overline{cg_w(k)}$值。具体的低通滤波器可选择下列一阶低通滤波器

$$\overline{cg_w(k)} = \alpha\overline{cg_w(k-1)} + cg_w(k) \qquad [公式 5]$$

或选择如下的滑动窗平均方法进行低通滤波

$$\overline{cg_w(k)} = \sum_{l=0}^{J-1} cg_w(k-l) \qquad [公式 6]$$

其中低通滤波参数α和 J 的选取视具体应用而定，选择的原则应使得低通滤波器的截止频率大于本地 PN 码时钟的绝对误差值。环路滤波单元的输出结果$\overline{cg_w(k)}$送往本地 PN 码相位调整部分进行本地 PN 码相位调整。

本地 PN 码相位调整部分主要完成公式 3 所示的运算。本发明采用对本地 PN 码发生时钟进行微调的方法，实现所需的本地 PN 码相位调整。图 2 示出了这种方法的实现框图。图中本地 PN 码时钟的发生是通过对一高倍（M 倍）外部时钟的分频计数来完成的，而码片时钟的微调又是通过可变模计数器来完成的。若$\overline{cg_w(k)}$取值为正，则计数器的模值取为$M-1$；若$\overline{cg_w(k)}$取值为负，则计数器的模值取为$M+1$；其它情况下计数器的模值取为 M。通过这种方法，可实现公式 3 所示的 PN 码相位调整，其微调的相位差为$\delta = T_c/M$。通常 M 的数值可取为 16 或 32，以保证足够精细的调整精度。

在实际应用中，可能需要对多个发送信号源所发送的导频信号进行同时跟踪。例如，在移动台需要对多个基站所发送的信号进行宏分集时便是如此。由于各个发送信号源到达接收端的路径是相互独立的，因而需要对各个信号源所发送的导频信号分别进行 PN 码的跟踪。由于多径能量窗的重心变化相对较慢，因而可使用时分复用的方式计算来自多个发送信号源的多径能量窗重心，并分别对各个发送信号源的导频信

号进行独立跟踪。图 3 示出了对多个发送信号源进行导频跟踪的实现方案。在该方案中，多径信道估计部分及能量窗重心计算部分采用时分复用的方式，以达到节省硬件资源的目的。而环路滤波以及 PN 码相位调整部分采用相互独立的并行工作方式。

实施例

本发明已应用于我们自行研制的符合 3GPP2 Release A 标准的 cdma2000-1x 蜂窝移动通信车载移动台样机中。该样机中的导频信道同步与跟踪部分采用 Xilinx 公司的 XC4085xla FPGA 芯片实现，其主要参数列举如下：

扩频码片速率 1.2288MHz；

I/Q 采样速率 4×1.2288MHz，6 比特输入；

多径能量窗参数选取为 $L=32, L_1=12, L_2=19$；

环路滤波采用滑动窗平均方式，参数 J 取值为 16；

外部时钟（EXT_CLK）39.3216MHz；

信道估计积分周期 384 个码片间隔（N = 384）；

相关器组（CORRELATION BANK）采用 16 倍时分复用方式；

每一物理相关器可实现 15 组有效相关运算。

经过实际测试，利用本发明所设计的多径能量窗重心导频跟踪环路在车载移动多径衰落环境下，较传统方法具有较好的稳健型。

权 利 要 求

1. 一种基于多径信道重心跟踪环路的导频信道跟踪方法，其特征在于由如下步骤组成：

（4） 估计多径衰落信道参数；

（5） 计算多径能量窗中心；

（6） 环路滤波及括频序列码相位调整。

2. 如权利要求 1 所述的基于多径信道重心跟踪环路的导频信道跟踪方法，其特征在于：

（1） 多径衰落信道参数估计由抽头延迟线和并行相关器两部分予以实现，前者接收基带采样信号，采样间隔为 T_c/M，后者受外部定时的控制，完成多径能量窗口内所有多径信道衰落参数$\overline{c_n}(k)$的计算；

（2） 多径能量窗重心计算由有效径选择单元及能量窗重心计算单元予以实现，前者接收前级多径信道估计输出结果，对$\overline{c_n}(k)$进行门限判决，后者完成$cg_w(k)$的计算：$cg_w(k)=\sum_n n|\overline{c_n}(k)|^2$，

（3） 环路滤波及括频序列码相位调整由环路滤波单元及本地扩频序列相位调整单元予以实现，前者对$cg_w(k)$进行低通滤波运算，后者采用对本地扩频序列码发生时钟进行微调的方法，实现所需的本地 PN 码相位调整。

3. 如权利要求 2 所述的基于多径信道重心跟踪环路的导频信道跟踪方法，其特征在于本地扩频序列码相位调整采用对本地扩频序列码发生时钟进行微调的方法，其中本地扩频序列码时钟的发生是通过对一高倍（M 倍）外部时钟的分频计数来实现的，而码片时钟的微调又是通过可变模计数器来完成。

4. 如权利要求 1 所述的基于多径信道重心跟踪环路的导频信道跟踪方法，其特征在于：使用时分复用的方式计算来自多个发送信号源的多径能量窗重心，并分别对各个发送信号源的导频信号进行独立跟踪。

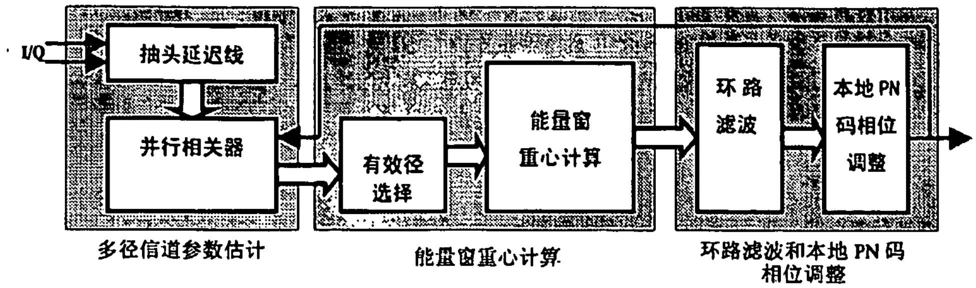

I/Q
抽头延迟线
并行相关器
有效径选择
能量窗重心计算
环路滤波
本地PN码相位调整
多径信道参数估计
能量窗重心计算
环路滤波和本地 PN 码相位调整

图 1

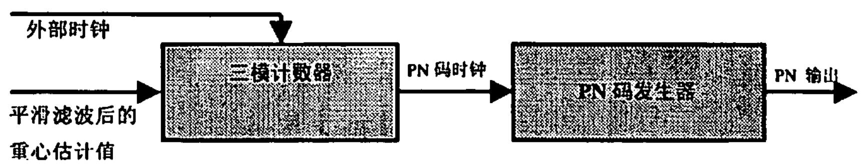

外部时钟
平滑滤波后的重心估计值
三模计数器
PN 码时钟
PN 码发生器
PN 输出

图 2

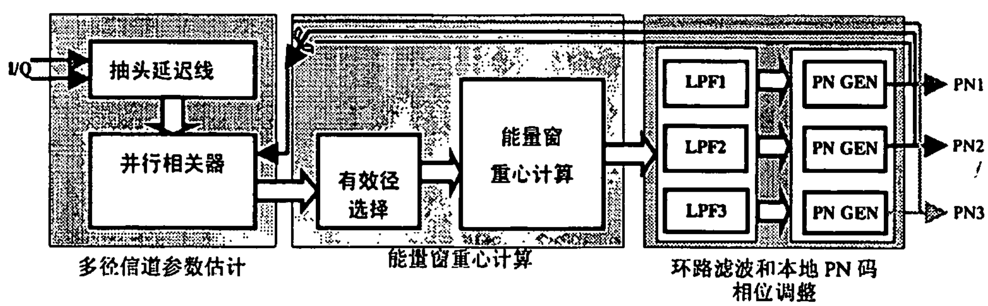

I/Q
抽头延迟线
并行相关器
有效径选择
能量窗重心计算
LPF1
LPF2
LPF3
PN GEN
PN GEN
PN GEN
PN1
PN2
PN3
多径信道参数估计
能量窗重心计算
环路滤波和本地 PN 码相位调整

图 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN01/01617

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04J13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04J13/00, H04Q7/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Pilot, channel, track, multipath, fading, energy, filter, spread

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN1147321A(Telefonaktiebolaget LM Ericsson)09.Apr.1997 (09.04.97) See page5,line9 to page6,line12, figure 1	1
Y	WO9631959A1(OKI TELECOM) 10 Oct.1996(10.10.96) See page 3, lines17-30	1
A	EP1001551A2(LUCENT TECHNOLOGIES INC.)17.May.2000(17.05.00) See entire	1-4

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 27.Jun..2002(27.062002)	Date of mailing of the international search report 11 JUL 2002
Name and mailing address of the ISA/CN 6 Xitucheng Rd., Jimen Bridge, Haidian District, 100088 Beijing, China Facsimile No. 86-10-62019451	Authorized officer 秦军 QIN, LIJUN 印力 Telephone No. 86-10-62093842

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN01/01617

Patent document Cited in search report	Publication Date	Patent family member(s)	Publication Date
CN1147321A	09.04.97	US5544156A	28.10.96
		WO9530289A2	09.11.95
WO9631959A1	10.10.96	AU5444596A	23.10.96
		US5627835A	06.05.97
EP1001551A2	02.11.99	CA228200A1	17.05.00
		JP2000151463A	30.05.00

国际检索报告	国际申请号 PCT/CN01/01617

A. 主题的分类

IPC⁷：H04J13/00

按照国际专利分类表(IPC)或者同时按照国家分类和 IPC 两种分类

B. 检索领域

检索的最低限度文献(标明分类体系和分类号)

IPC⁷：H04J13/00 H04Q7/00

包含在检索领域中的除最低限度文献以外的检索文献

在国际检索时查阅的电子数据库(数据库的名称和，如果实际可行的，使用的检索词)

pilot,channel, track, mutilpath, fading, energy, filter, spread

C. 相关文件

类　型*	引用文件，必要时，指明相关段落	相关的权利要求编号
Y	CN1147321A（爱立信电话股份有限公司） 9.4 月 1997（09.04.97） 说明书第 5 页 9 行至第 6 页 12 行，图 1	1
Y	WO9631959A（OKI TELECOM） 10.10 月 1996 年（10.10.96） 说明书第 3 页 17 行至 30 行	1
A	EP1001551A2（LUCENT 技术公司） 17.5 月 2000 年（17.05.00） 全文	1-4

☐ 其余文件在 C 栏的续页中列出。　　☒ 见同族专利附件。

* 引用文件的专用类型：

"A" 明确叙述了被认为不是特别相关的一般现有技术的文件

"E" 在国际申请日的当天或之后公布的在先的申请或专利

"L" 可能引起对优先权要求的怀疑的文件，为确定另一篇引用文件的公布日而引用的或者因其他特殊理由而引用的文件

"O" 涉及口头公开、使用、展览或其他方式公开的文件

"P" 公布日先于国际申请日但迟于所要求的优先权日的文件

"T" 在申请日或优先权日之后公布的在后文件，它与申请不相抵触，但是引用它是为了理解构成发明基础的理论或原理

"X" 特别相关的文件，仅仅考虑该文件，权利要求所记载的发明就不能认为是新颖的或不能认为是有创造性

"Y" 特别相关的文件，当该文件与另一篇或者多篇该类文件结合并且这种结合对于本领域技术人员为显而易见时，权利要求记载的发明不具有创造性

"&" 同族专利成员的文件

国际检索实际完成的日期 2002 年 6 月 27 日	国际检索报告邮寄日期 11. 7月 2002 (11.07.02)
国际检索单位名称和邮寄地址 ISA/CN 中国北京市海淀区西土城路 6 号(100088) 传真号：86-10-62019451	受权官员 秦力军 军秦印力 电话号码：86-10-62093342

国际检索报告
关于同族专利成员的情报

国际申请号
PCT/CN01/01617

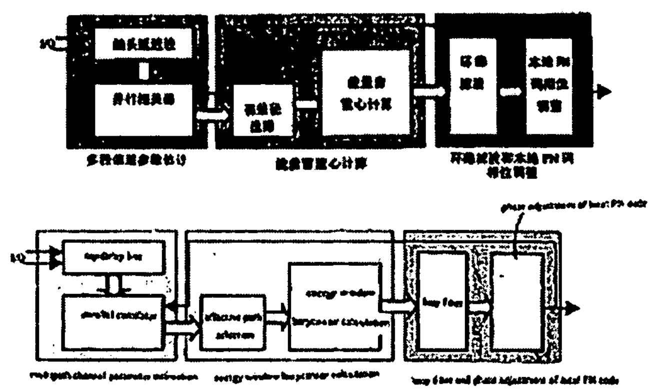
检索报告中引用的专利文件	公布日期	同族专利成员	公布日期
CN1147321A	09.04 月 97 年	US5544156A	28.10.96
		WO9530289A2	09.11.95
WO9631959A1	10.10 月 96 年	AU5444596A	23.10.96
		US5627835A	06.05.97
EP1001551A2	02.11 月 99 年	CA2282800A1	17.05.00
		JP2000151463A	30.05.00

PILOT CHANNEL TRACKING METHOD BASED ON MULTIPATH BARYCENTER TRACKING LOOP

Patent number:	WO02080423	**Also published as:**
Publication date:	2002-10-10	US2004095957 (A1)
Inventor:	CHENG SHINXIN (CN); ZHAO CHUNMING (CN); GUO JINGHONG (CN); YOU XIAOHU (CN)	
Applicant:	CHENG SHINXIN (CN); ZHAO CHUNMING (CN); GUO JINGHONG (CN); YOU XIAOHU (CN); RES INST OF TELECOMM TRANSMISS (CN); SOUTHEAST UNIVERSITY (CN)	**Cited documents:** CN1147312 WO9631959 EP1001551
Classification:		
- international:	H04J13/00	
- european:	H04B1/707F3	
Application number:	WO2001CN01617 20011212	
Priority number(s):	CN20000128222 20001218	

Abstract of **WO02080423**

A pilot channel tracking method based on multipath barycenter tracking loop, comprising: 1) estimating parameter of multipath fading channel; 2) calculating multipath energy window center; 3) adjusting loop-filter and spread sequence code phase. The present invention does not need to individually track each delay path, thereby advancing a tracking performance of spread receiver and a stability of timing restoring. For a tracking of pilot signal transmitted by multi-transmitting signal source, only a multipath channnel estimator and a multipath energy window barycenter calculator are made in TDM, thereby saving hardware resource. Therefore, an integral new type coherent spread receiver can be constituted by cooperating with other part each other.



PILOT CHANNEL TRACKING METHOD BASED ON MULTIPATH BARYCENTER TRACKING LOOP

Description of correspondent: **US2004095957**

FIELD OF THE INVENTION

[0001] The present invention relates to a CDMA (code division multiple access) cellular communication system, more specifically, to a method for pilot channel tracking based on multipath channel barycenter tracking loop.

BACKGROUND OF THE INVENTION

[0002] CDMA cellular communication technique shows great potential for its features associated with large capacity, simple frequency planning, good communication quality and small electromagnetic interference. CDMA spread spectrum receivers are classified into coherent receivers and non-coherent receivers. Coherent receivers need the phase information of received signals, and non-coherent receivers do not need the phase information, but need the transmitted signal in quadrature modulating. The present invention pertains to coherent receiving mode in future CDMA cellular communication systems.
[0003] Multipath fading which causes serious multipath interference exists in a mobile communication system. In general, it is necessary to receive pilot signals with confirmation information so as to evaluate the amplitude and phase information of multipath signals so that it is possible to achieve multipath diversity and coherent reception. A coherent spread spectrum receiver which performs diversity processing is referred to as RAKE coherent receiver. RAKE coherent receivers can correct phases of a plurality of singlepath signals which carry same information and are independence from one another in fading features, and perform maximal combination to overcome multipath fading and improve received signal-to-interference ratio.
[0004] To achieve RAKE reception function, Synchronizing local spread spectrum sequence (PN code) with received signal is necessary. The synchronization is achieved by acquiring and tracking steps. The acquiring step acquires a pilot channel and confirms that initial synchronization (coarse synchronization) of PN code is complete. The tracking step finely synchronizes the PN codes by tracking pilot signals. The combination of these two steps provides PN code and accurate local timing required for a RAKE receiver.
[0005] Conventional PN code tracking method is based on so-called "early-late-gate" technique which finely adjusts phase of local PN code by observing and comparing the average energy in lead timing and lag timing of current pilot signals so as to finely synchronizing PN codes. In the case where multipath arrival signals exist, effective arrival signals from each of paths are subjected to "early-late-gate" processing to achieve fine synchronization to multipath signals. Unfortunately, random changes in both the amplitude and phase of the arrival signals from each of paths occur in a large range due to the serious fading in mobile communication systems. The tracking procedure for signals from each of paths became extremely unstable as the fading of the signals if conventional "early-late-gate" technique is used. Further, the local timing for a receiver is generally established based on the signals from the earliest effective arrival path. Therefore, the establishment of local timing for a receiver lacks stability because the signals from the earliest effective arrival path are extremely unstable.

SUMMARY OF THE INVENTION

[0006] It is therefore an object of the present invention to provide a method for pilot channel tracking based on multipath channel barycenter tracking loop. The present invention provides a concept of multipath energy window and algorithms for calculating the barycenter of energy window to establish the method for pilot channel tracking based on multipath channel barycenter tracking loop, thereby overcoming degradation of the tracking performance for multipath signal and the non-determinacy of recovering local timing signals due to the early-late-gate processing method.
[0007] To achieve above object, it provides a method for pilot channel tracking based on multipath channel barycenter tracking loop comprising steps:
[0008] evaluating multipath fading channel parameters;
[0009] calculating the barycenter of a multipath energy window; and
[0010] loop filtering and adjusting phase of spread spectrum sequence codes.
[0011] According to this invention, it is not necessary to individually track each delay path, the tracking performance and stability of recovering timing for a spread spectrum receiver are therefore improved. For tracking pilot signals transmitted from a plurality of signal sources, it needs only a multipath signal evaluator and a multipath energy window barycenter calculating circuit in a manner of time division

multiplexing, and reduces hardwares for receiver. A novelty coherent spread spectrum receiver can be constituted by cooperating with other parts.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above and other objects, features, and advantages of the present invention will become apparent from the following description with reference to the accompanying drawings, which illustrate examples of the present invention.

[0013] FIG. 1 schematically illustrates a flowchart of the method according to an embodiment of the invention;

[0014] FIG. 2 schematically illustrates a block diagram of PN code phase adjustment according to an embodiment of the invention; and

[0015] FIG. 3 schematically illustrates a block diagram of a multipath energy window barycenter tracking loop which is suitable for a plurality of signal transmitting sources.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Referring now to the accompanying drawings, there are shown preferred embodiments of the method for pilot channel tracking based on multipath channel barycenter tracking loop according to the invention.

[0017] This invention provides a method for pilot channel tracking based on multipath channel barycenter tracking loop. This method bases on following facts: the energy window and barycenter position of multipath signals are relative stable although the amplitude and phase of arrival signals from each path change randomly The PN code tracking method according to the Invention is capable of overcoming the non-determinacy of system timing and PN code tracking characteristic due to the early-late-gate processing for singlepath signals by adjusting the local PN code, determining the local timing for the coherent receiver, and selecting effective multipath within the energy window based on the change of barycenter position of the multipath energy window. The stability of the coherent spread spectrum receiver can be improved. This invention also provides a parallel processing method for the multipath energy window so that the achievement of the functions which track pilot signals, recover local timing, coherently combine RAKE diversity, AFC and search a plurality of cells is possible.

[0018] The method according to the present invention comprises steps:

[0019] 1. Evaluating Multipath Fading Channel Parameters

[0020] A pilot channel in a CDMA system is used for transferring a pilot sequence known in advance which may provide a system timing, extract carriers, evaluate channels, and execute hand-off, etc. An equivalent baseband receiving signals may be expressed as equation (1) when the system simultaneously transmits signals through a plurality of channels,

EMI1.1

[0021] wherein di and si(t) represent the signs and equivalent baseband signals transmitted through ith code division channel in downstream channels. The term of i=0 corresponds to the pilot channel. In general, it assumes that the sign transmitted by a pilot channel is d0=0, 1/W=Tc is the time width of one chip, z(t) is complex White Gaussian noise of zero average value, cn is a fading factor of nth path of the channels. The purpose for evaluating channel parameter is to evaluate channel fading factor cn based on the received signals r(t) and the known pilot sequence s0(t).

[0022] It is assumed that a frequency selectivity slow fading channel model is used as a mobile channel, cn is then approximate to a constant within the channel evaluation region. The evaluation value of cn is given as follow:

EMI2.1

[0023] wherein Na, Nc, and Nz are the outputs caused by multipath interference, multiple access interference and white noise passed through a correlator due to the non-ideal correlation characteristic, Tc is a time width of one chip, NTc is an integration region of a channel evaluation, and Ec is energy transmitted through a pilot channel within one chip.

[0024] 2. Multipath Energy Window and Barycenter Calculation Thereof

[0025] The effective distribution range of channel fading factor cn in equation (1) is defined as multipath signal energy distribution window (hereinafter is referred to as multipath energy window), The size of the window may be determined by time-delay extend range of multipath channels. For the sake of simplifying discussion, the effective distribution range of cn may be set to n[epsilon][-L1,L2]. The size of the window in multipath fading circumstances may be set differently for different areas, for example, 3 [mu]s for cities, 6 [mu]s for countries, and 15 [mu]s for mountain areas. The size of window is associated with circumstance

where the cellular communication system is located, and is regardless of the used frequency band. The size of multipath energy window may be selected according to the maximal possible value, for example, no more than 30 [mu]s, and then the value of L=L2-L1+1 is not more than 30 [mu]s/Tc, so that a spreading receiver can be used in various circumstances.

[0026] In multipath energy window, not all signal arrival paths are effective. To this end, a threshold may be set to judge the signal energy (i.e., intensity of cn) for each of paths in a window. A signal arrival path is judged as effective path when the signal energy is larger than the threshold. Otherwise, the path is judged as a pure interference path. To avoid the degradation of the performance, the calculation is not applied to all pure interference paths. The threshold is set slightly larger than the side lobe value of a pilot signal (PN code) partial correlation value.

[0027] If K denotes the evaluated result of kth channel, the barycenter of corresponding multipath energy window is given by cg(k)=cgw(k)/cg,(k), wherein cgw(k) and cgs(k) are calculated as follows:

EMI3.1

[0028] wherein n corresponds to the position where the multipath fading factor cn(k) locates in multipath energy window. It should be noted that each of {overscore (cn)}(k)s to be operated in equation (3) is effective signal arrival path which is large than designated threshold.

[0029] 3. Loop Filter and Phase Adjustment of Local PN Code

[0030] PN code tracking loop for multipath energy window barycenter is designed such that the target position of multipath energy window barycenter is set to cgt arg et so that the PN code phase of the receiver can be adjusted by detecting the difference between the multipath energy window barycenter value cg(k) and cgt arg et to reduce the difference. For simplifying the calculation, it is assumed that cgt arg et is set to zero, the phase adjustment of local PN code can be then performed by simply judging the polarity of cgw(k), but not need to calculate cgs(k) and cg(k).

[0031] To avoid incorrect adjustment due to the random changes of multipath fading signals and channel evaluation errors, the barycenter evaluating value calculated by equation (3) is smoothly filtered. Assuming the smoothly filtered evaluating value is {overscore (cgw(k))}, the adjusting operation can be generalized to:

let the phase of local PN code lead [delta] if {overscore (cgw(k))}>0

let the phase of local PN code lag [delta] if {overscore (cgw(k))}<0

let the phase of local PN code hold if {overscore (cgw(k))}=0 (4)

[0032] An embodiment of the invention is described with reference to the accompanying drawings.

[0033] As described above, the method for pilot channel tracking based on multipath channel barycenter tracking loop comprises evaluating multipath channel, calculating the barycenter of the energy window and loop filtering, and adjusting the phase of PN code. FIG. 1 shows a block diagram of a multipath energy window pilot tracking. The configuration and the functions of each of parts in FIG. 1 are discussed as follows.

[0034] Multipath channel evaluating unit comprises a tap delay line unit and a parallel correlator. The tap delay line unit receives baseband sampling signals. The sampling interval may be set to Tc/M, and M may be set to, for example, 2, 4, or 8 as desired. The parallel correlator is controlled by an external timing to calculate all multipath channel fading parameters {overscore (cn)}(N) within the multipath energy window, and the obtained result is processed in a multipath energy window barycenter calculating means.

[0035] The multipath energy window barycenter calculating means comprises an effective path selecting unit and a multipath energy window barycenter calculating unit. The effective path selecting unit receives the multipath channel evaluating output from previous stage and judges whether {overscore (cn)}(k) is larger than the threshold so as to determine whether the received signals are from effective arrival paths. It should be noted that the threshold is set slightly larger than the side lobe value of a pilot signal (PN code) partial correlation value. A {overscore (cn)}(k) is set to zero if the amplitude of {overscore (cn)}(k) is smaller than set threshold. The multipath energy window barycenter calculating unit performs equation (3) to calculate cgw(k). The calculated result is provided to a loop filter unit.

[0036] With regard to loop filter and phase adjustment of local PN code, a loop filter unit lowpass filters cgw(k) to obtain {overscore (cgw(k))} value required for PN code phase adjustment. The lowpass filter may select following one order lowpass filter,

{overscore (cgw(k))}=[alpha]{overscore (cgw(k-1))}+cgw(k) (5)

[0037] or select slide window average method to perform lowpass filter,

EMI4.1

[0038] The selection of lowpass filter parameters [alpha] and J is dependent upon concrete requirements such that the cut-off frequency of the lowpass filter is larger than the absolute error value of the local PN code. The output {overscore (cgw(k))} from the loop filter unit is supplied to a local PN code phase adjusting unit to adjust the phase of the PN code.

[0039] The local PN code phase adjusting unit performs the operation shown in equation (3). According to an embodiment of the present invention, the local PN code phase adjustment is executed by finely adjusting the transmitting clock of local PN code. FIG. 2 illustrates an operation flowchart of the method according to the invention. In FIG. 2, the PN code clock is generated by counting the frequency division of a multiple times (M times) external clock. A variable mode counter finely adjusts the chip clock. The mode value of the counter is M-1 if the {overscore (cgw(k))} is positive. The mode value is M+1 if the {overscore (cgw(k))} is negative. Otherwise, the mode value of the counter is M. In this way, the PN code phase can be adjusted, and the phase difference of fine adjustment is [delta]=Tc/M, wherein M may be 32 or 64 to ensure the adjustment accuracy enough.

[0040] In practice, it is possible to simultaneously track pilot signals transmitted from a plurality of signal sources. For example, a mobile station executes macro-diversity on the signals transmitted from a plurality of base stations. The pilot signals from each of the signal sources are tracked respectively since the paths arriving at a receiving terminal from each of signal sources are independent from one another. The barycenter of multipath energy window from a plurality of signal sources can be calculated in time division multiplexing manner and the pilot signals from each of signal sources can be tracked respectively since the multipath energy window barycenter changes slowly. FIG. 3 shows a schematic diagram of tracking pilot signals from a plurality of signal sources. The multipath channel evaluating unit and the multipath energy window barycenter calculating unit may operate in time division multiplexing manner for reducing hardware. The loop filter and PN code phase adjusting unit may operate independently from each other in parallel.

EXAMPLE

[0041] Next, the implement of the present invention is described with a mobile terminal in CDMA 2000-1x system used as an example. The mobile terminal may be a vehicle mobile station in CDMA2000-1x cellular mobile communication system fitting Standard 3GPP2 Release A. The pilot channel synchronizing and tracking parts can be implemented by, for example, a XC4085xla FPGA chip, a product of Xilinx company. The main parameters are listed as follows:

[0042] Spreading chip rate is 1.2288 MHz;

[0043] I/O sampling rate is 4*1.2288 MHz, 6 bits input;

[0044] Multipath energy window parameters are set to L=32, L1=12, L2=19;

[0045] Loop filtering uses slide window average manner, parameter J is set to 16;

[0046] External clock (EXT_CLK) is 39.3216 MHz;

[0047] Integrating period for channel evaluating is 384 chip intervals (N=384);

[0048] Correlator bank uses a 16-times time division multiplexing manner;

[0049] Each of physical correlators may execute 15 banks of effective correlation operation.

[0050] The pilot tracking loop for multipath energy window barycenter can provide excellent stability in the circumstances of vehicle mobile terminals.

[0051] Although embodiments of the present invention have been shown and described, it will be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the appended claims and their equivalents.

PILOT CHANNEL TRACKING METHOD BASED ON MULTIPATH BARYCENTER TRACKING LOOP

Claims of correspondent: **US2004095957**

What is claimed is:

1. A method for pilot channel tracking based on multipath channel barycenter tracking loop comprises steps:
evaluating multipath fading channel parameters;
calculating the barycenter of a multipath energy window; and
loop filtering and adjusting the phase of spread spectrum sequence codes.

2. The method for pilot channel tracking based on multipath channel barycenter tracking loop according to claim 1, wherein the step of evaluating multipath fading channel parameters is executed by a tap delay line unit and a parallel correlator, wherein the tap delay line unit receives baseband sampling signals whose interval is Tc/M, and the parallel correlator calculates fading parameters {overscore (cn)}(k) of all multipath channels within the multipath energy window under the control of an external clock,
the step of calculating the barycenter of the multipath energy window is executed by an effective paths selecting unit and an multipath energy window barycenter calculating unit, wherein the effective paths selecting unit receives the evaluating output results of multipath channels in previous stage and comparing the {overscore (cn)}(k) with a threshold, and the multipath energy window barycenter calculating unit calculates cgw(k) with the equation

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the step of loop filtering and adjusting phase of spread spectrum sequence codes is executed by a loop filter unit and a local spread spectrum sequence phase adjusting unit, wherein the loop filter unit filters the cgw(k), and the local spread spectrum sequence phase adjusting unit finely adjusts a local spread spectrum sequence clock to adjust the phase of the local PN code.

3. The method for pilot channel tracking based on multipath channel barycenter tracking loop according to claim 2, wherein the step of adjusting the phase of the local spread spectrum sequence is executed by finely adjusting the local spread spectrum sequence clock, wherein the local spread spectrum sequence clock is generated by counting the frequency division of a multiple times (M times) external clock, a variable mode counter finely adjusts a chip clock.

4. The method for pilot channel tracking based on multipath channel barycenter tracking loop according to claim 1, wherein the barycenter of the multipath energy window from a plurality of signal sources is calculated in a manner of time division multiplexing, and the PN signals from each of signal sources is tracked respectively.